Table 1. The Berea sandstone core properties

Core #	D_2 cm	L, cm	K_g, md	ϕ, %	S_{wi},%	μ_o, cp	Wetness
Soltrol 220, no aging							
Ev8h8b	3.764	7.91	73.9	0.1615	22.6	3.8	VSWW
Ev8h9a	3.739	8.057	82.9	0.1601	20.9	3.8	VSWW
Ev8h9b	3.742	7.922	76.7	0.1588	24.6	3.8	VSWW
Ev8h10a	3.761	8.047	76.7	0.1636	22.7	3.8	VSWW
Ev8h10b	3.764	7.83	70.1	0.1627	22.5	3.8	VSWW
Ev8h17a	3.763	8.245	77.4	0.1734	22.59	3.8	VSWW
Ev8h18a	3.753	7.894	95.8	0.1746	23.02	3.8	VSWW
Minnelusa 2002 crude oil							
Ev8h1a	7.864	3.786	101.5	0.1760	23.9	68.0	MXW, 10d aging
Ev8h2b	7.538	3.765	71.7	0.1652	23.7	68.0	MXW, 10d aging
Ev8h3a	3.764	7.963	70.1	0.1678	24.3	1.5	MXW-F (Dakota) , 10d aging
Ev8h4a	3.764	8.06	65.1	0.1636	24.3	68.0	MXW, 10d aging
Ev8h4b	7.680	3.767	66.6	0.1628	24.6	680	MXW, 1d aging
Ev8h5a	8.242	3.764	68.2	0.1649	24.6	68.0	MXW, no aging
Ev8h5b	3.766	7.754	74.6	0.1664	24.4	3.8	MXW-F (S220), no aging
Ev8h6b	7.736	3.764	67.6	0.1605	22.0	68.0	MXW, 10d aging
Ev8h7b	3.765	7.67	72.4	0.1603	22.5	1.5	MXW-F (Dakota) , no aging
Ev8h11b	3.758	7.791	120	0.1743	22.8	1.5	MXW (Dakota) , no aging
Ev8h13a	3.758	8.105	126.2	0.1754	23.2	68.0	MXW, no aging
Ev8h16a	8.280	3.759	114.0	0.1778	22.1	68.0	MXW, 10d aging
Ev8h16b	3.76	7.921	117.2	0.1774	21.3	68.0	MXW, 10d aging
Ev8h29a	3.75	8.262	133.1	0.1749	18.8	68.0	MXW, 4d aging, 45°C
Ev7v1b	7.644	3.788	58.2	0.1748	23.3	68.0	MXW, 10d aging
Ev1v1d	3.777	7.581	46.2	0.1703	22.0	68.0	MXW, 10d aging
Ev5h1c	3.787	7.634	113	0.182	23.9	68.0	MXW, 10d aging
Tensleep 95 crude oil							
Ev8h13b	3.758	7.835	119.3	0.1731	21.3	19.2	MXW, 10d aging
Ev8h14a	3.759	8.076	109.6	0.1717	22.6	19.2	MXW, no aging
Ev8h14b	3.76	7.839	106.2	0.1708	22.0	1.5	MXW-F (Dakota) , no aging
Ev8h15a	3.757	8.228	111.1	0.1778	22.2	1.5	MXW-F (Dakota) , no aging
Ev8h15b	3.759	7.974	114.4	0.1776	22.7	19.2	MXW , no aging
Ev8h21b	3.758	7.686	87.6	0.174	22.6	33.9	MXW-F (frontier) , no aging
Big Sand Draw crude oil							
Ev8h19a	3.756	7.866	70.9	0.1698	23.1	3.8	MXW-F (S220) , no aging
Ev8h21a	3.758	7.832	84.8	0.1724	23.3	7.0	MXW, no aging
Ev8h27b	3.750	7.758	119.7	0.1741	23.6	7.0	MXW , no aging
Ev8h28b	3.750	8.056	121.2	0.1794	22.3	7.0	MXW, 10d aging
Ev8h30a	3.748	7.597	86.8	0.1705	<24.7	7.0	MXW, 2d aging
Ev8h30b	3.752	7.153	86	0.1717	<26.3	7.0	MXW, 2d aging

Table 2. The Limestone core properties

Core #	D, cm	L, cm	K_{ip}, md	ϕ, %	S_{wi},%	μ_o, cp	Wetness
Oil recovery (Cottonwood oil)							
1TC15a	3.724	7.477	19.1	0.2696	24.3	24.1	MXW, 10d aging
T2Tc11a	3.729	7.320	14.7	0.2767	18.59	24.1	MXW, 10d aging
T2Tc21a	3.698	7.797	7.1	0.2300	22.12	24.1	MXW, 10d aging
Gas flooding							
1TC8b	3.734	6.59	3.7	18.0	100		VSWW
1TC20b	3.749	7.452	6.1	21.6	100		VSWW
1TC24b	3.753	7.593	3.6	18.0	100		VSWW
3TC18b	3.740	6.490	1.4	20.2	21.4		VSWW
2TC4b	3.788	6.481	3.4	22.8	21.7		Tensleep/S130, 2d aging
1TC24b	3.753	7.593	3.6	18.0	27.5		BS oil (the 2nd and 3rd cycle), 2d aging

Table 3. Selected properties of crude and refined oils

Oils		ρ, g/mL @20°C	η, cP @~22°C	IFT, mN/M @20°C	Asphalt.%
Asphaltic crudes	Minnelusa 2002	0.9076	68	23.4	9.5
	Black Mt.	0.9219	134		8.1
	Tensleep 95	0.8692	19.2	23.3	3.2
	Cottonwood	0.8874	24.1	28.9	2.3
	Big Sand Draw	0.8496	7.0	21.5	1.6
Mineral oils	S220	0.7869	3.8	49.5	0
	S130	0.7605	1.6	~50	0
	Pentane			~50	0
Paraffinic crudes	Dakota	0.7741	1.5	34.2	0
	Frontier	0.8338	21.8	33.8	0

Table 4. Synthetic brine composition

Brine	NaCl (g/L)	KCl (g/L)	$CaCl_2$ (g/L)	$MgCl_2$ (g/L)	NaN_3 (g/L)	pH	TDS (mg/L)
Sea water	28	0.935	2.379	5.365	0.1	6.6	36779

Table 5 Interfacial tensions (Aqueous phase = SSW)

Oleic phase	IFT, mN/m	Temp.,°C
S220	49.5	20.0
S220	1.7	20.0
S220+0.025%polyamine	24.3	20.0
S220+0.2%RAP	0.03	20.0
S220+0.05%RAP	0.55	20.0
S220+0.025%PA+0.05%RAP	1.0	20.0
S220+0.2%TDA-6	1.34	20.0
S220+0.1%DA-4	11.7	20.0
S220+0.1%oleic acid	29.8	20.0
Minnelusa 2002 crude oil	23.4	20.0
Dakota crude oil	34.2	20.0
Tensleep 1995 crude oil	23.3	20.0
Big SandDraw crude oil	21.5	20.0
Frontier crude oil	33.8	20.0
M'02 +0.025%PA	17.7	20.0
M'02+0.05%RAP	8.6	20.0
Dakota oil+0.025%PA	7.9	20.0
Tensleep 95 +0.05%PA	10.5	20.0
BS oil +0.05%PA	10	20.0
BS oil + 0.1%PA	7.2	20.0
BS oil + 0.1%PA	4.3	75.0
Cottonwood oil +0.025% PA	12.1	20.0
Cottonwood oil	28.9	20.0

Table 6 Asphaltene precipitation

	Minnelusa crude	Black Mountain crude	Tensleep crude	Big Sand Draw
S220 or S130	Yes	Yes	Yes	Yes
Dakota oil	Yes	Yes	Yes	Yes
Frontier oil		Yes (under microscope)	No	No

Fig. 1 Method 1 of treatment for oil reservoir case

Fig.1a

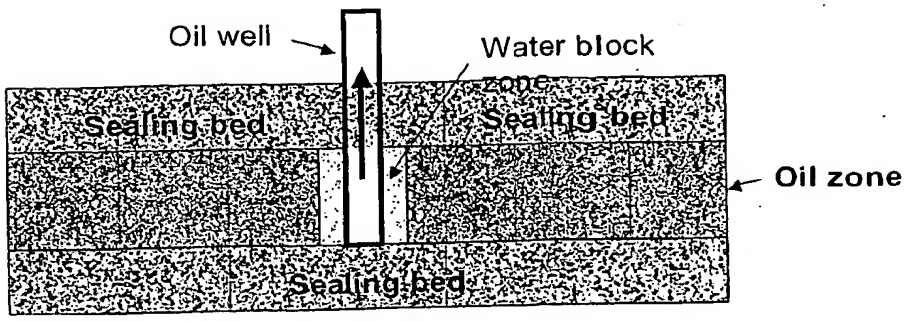
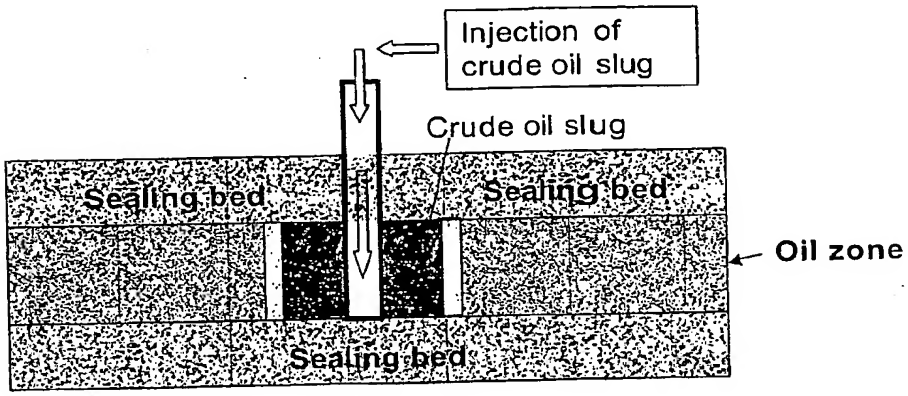


Fig.1b



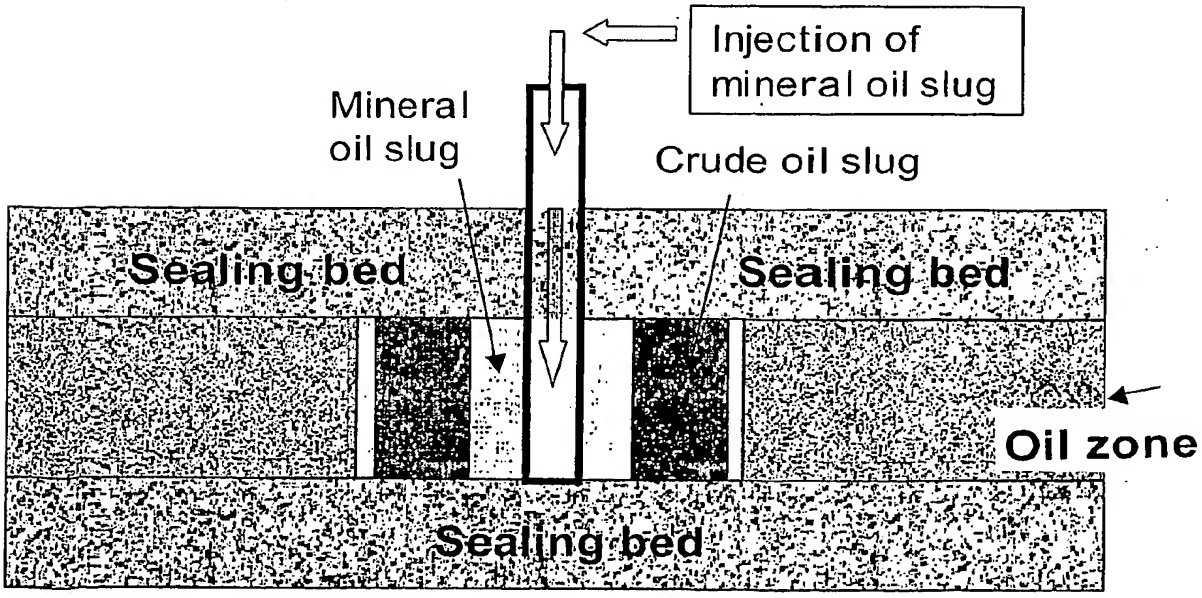


Fig.1c

Fig.1d

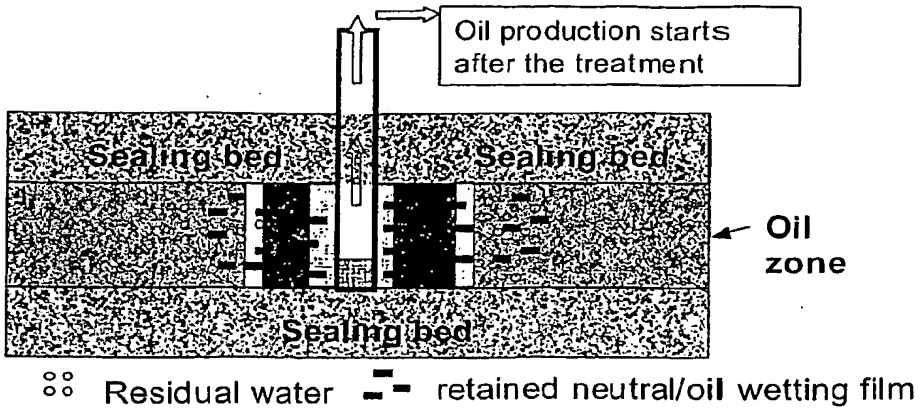


Fig.1e

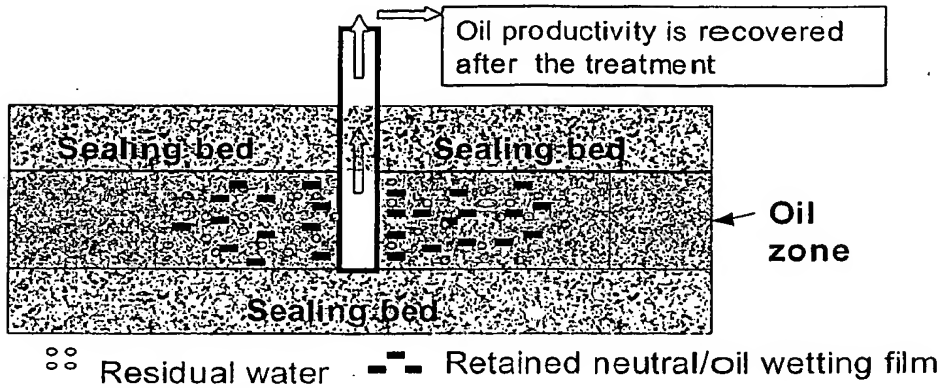


Fig. 2 The sketch of water saturation change near well bore vs. cycle numbers of treatment

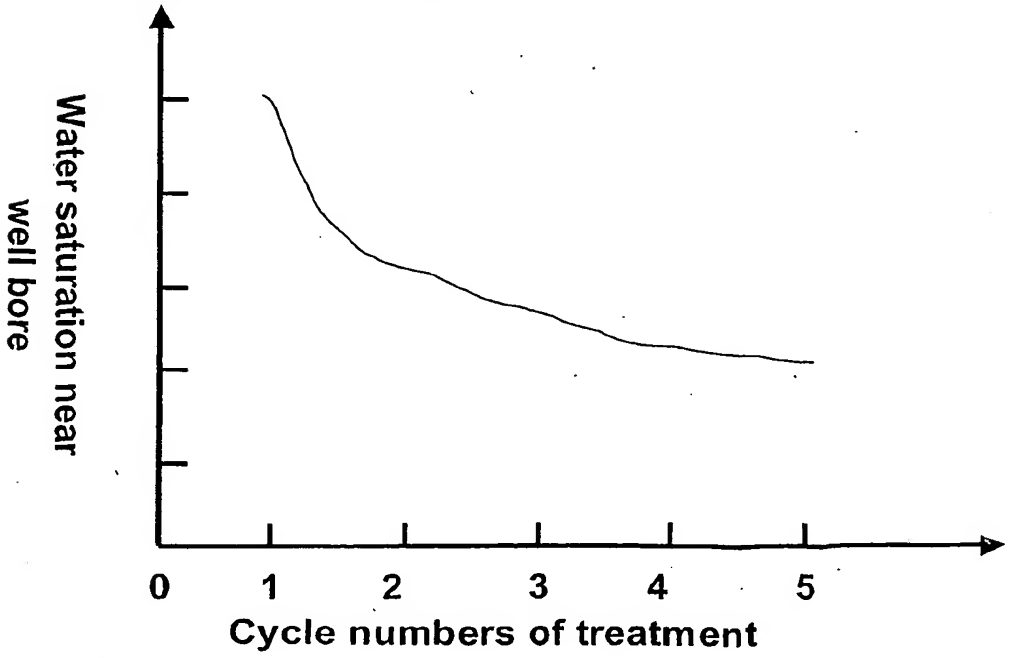


Fig. 3 Method 2 of treatment for oil reservoir case

Fig.3a

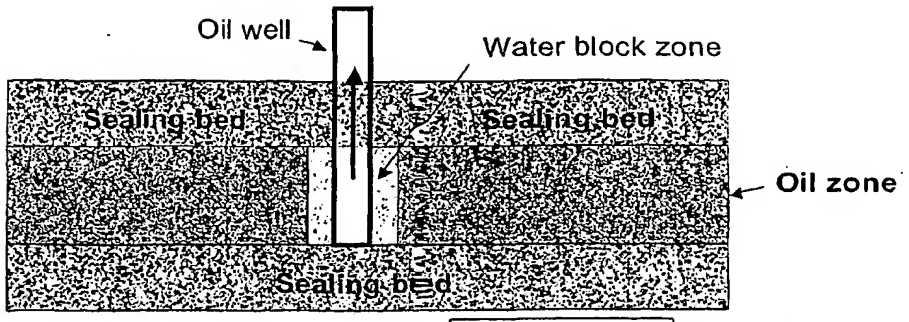


Fig.3b

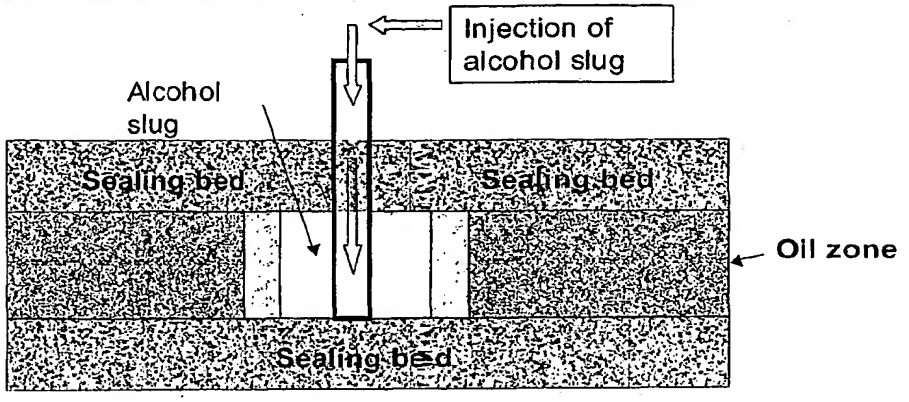


Fig.3c

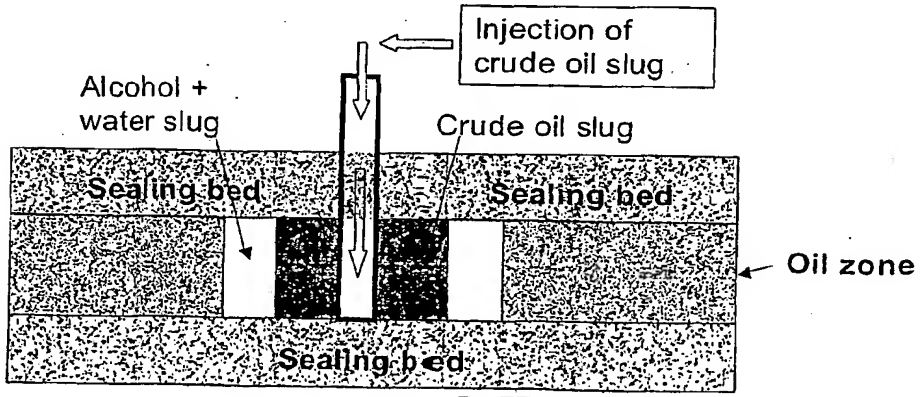


Fig.3d

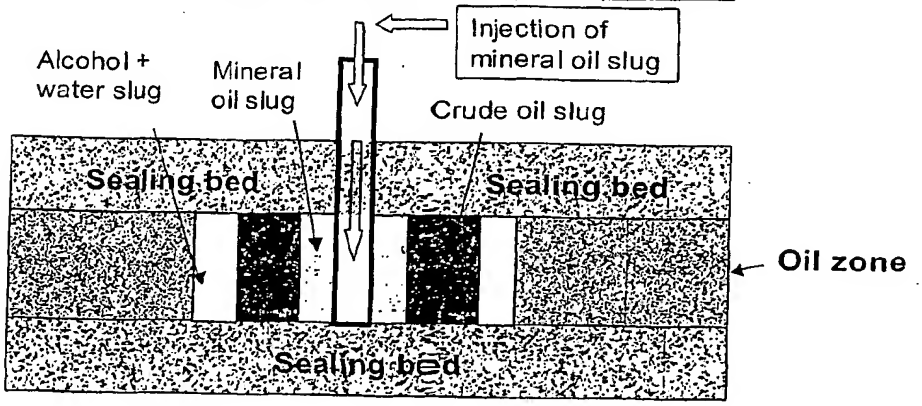


Fig.3e

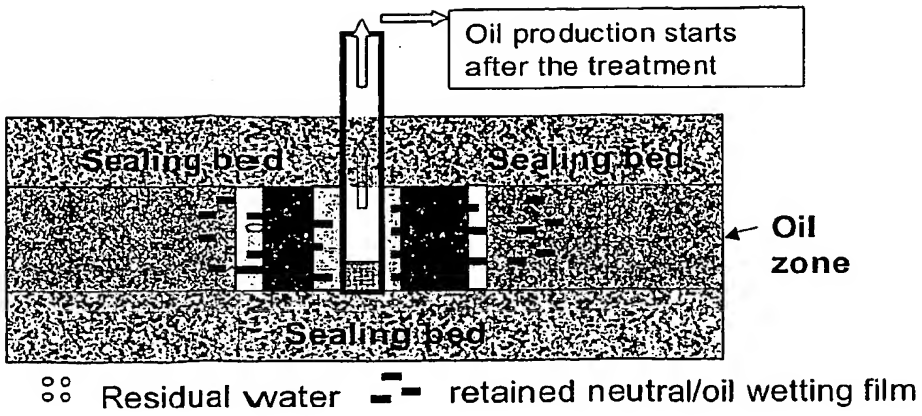


Fig.3f

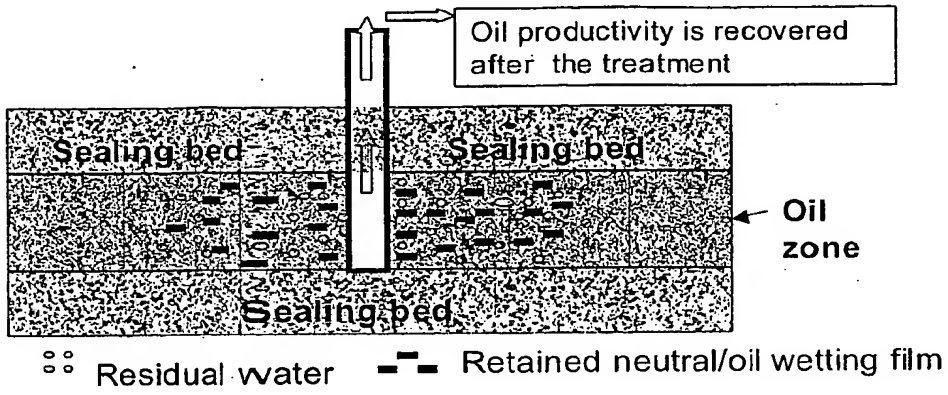


Fig. 4 Method 1 of treatment for gas or gas condensate reservoir case

Fig.4a

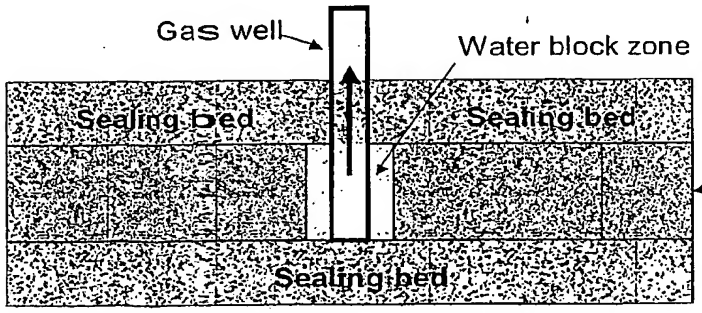


Fig.4b

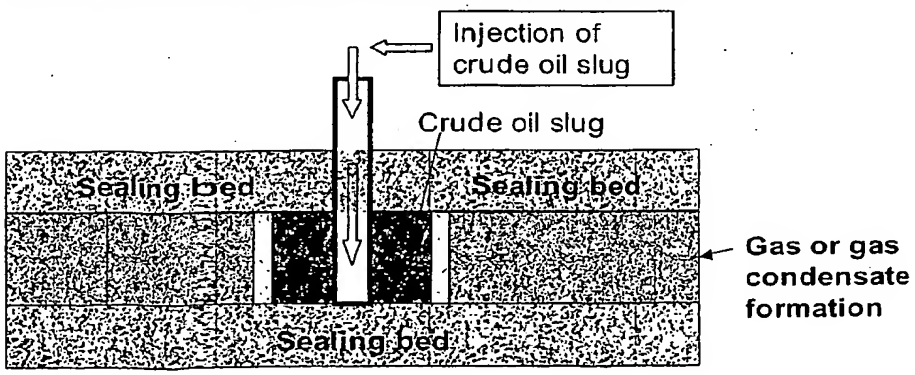


Fig.4c

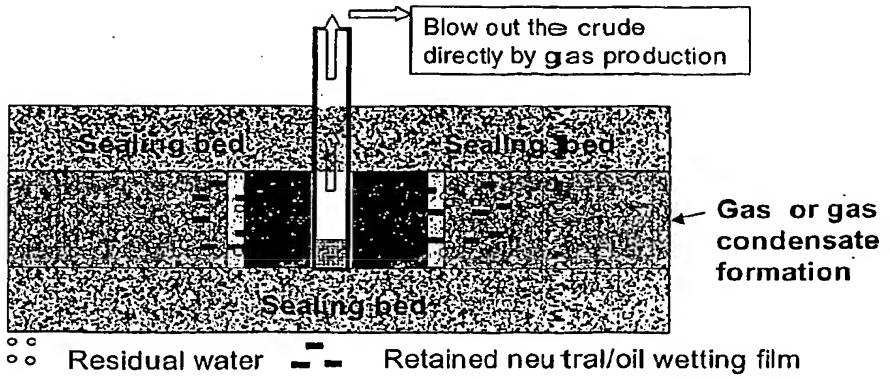


Fig. 4d

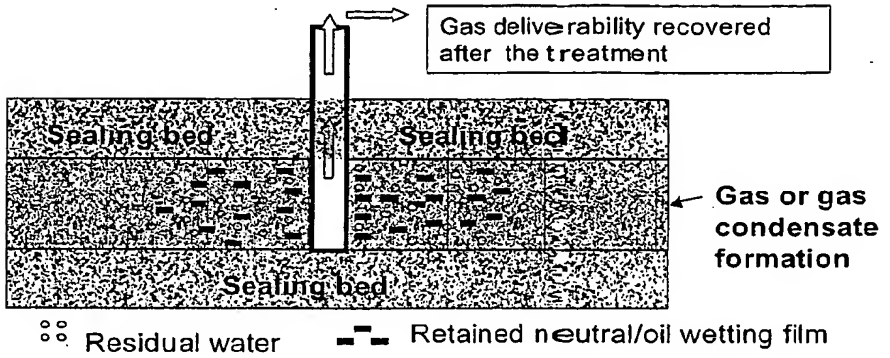


Fig. 5 Method 2 of treatment for gas or gas condensate reservoir case

Fig.5a

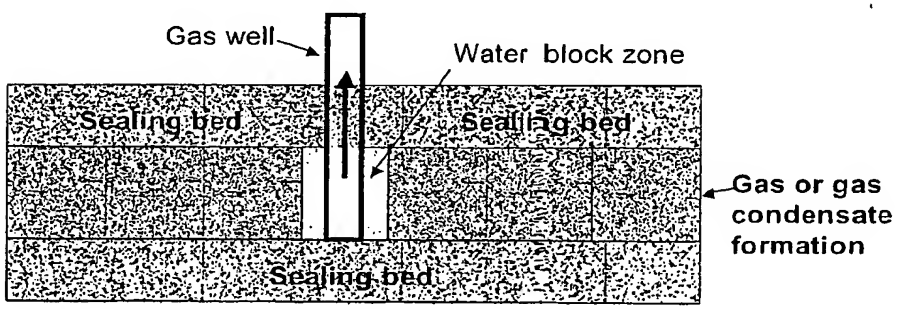
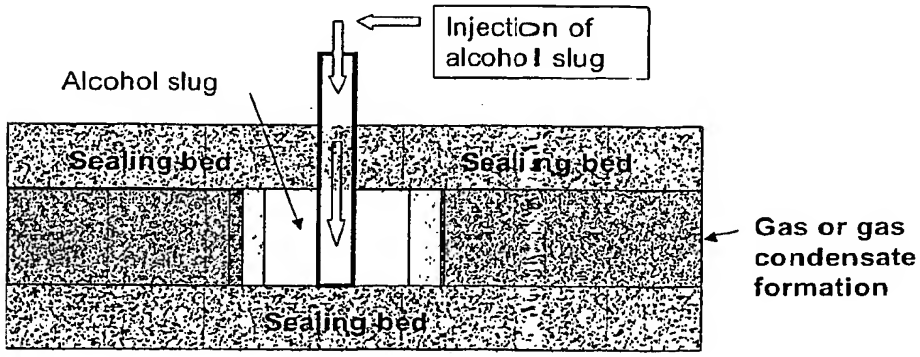


Fig.5b



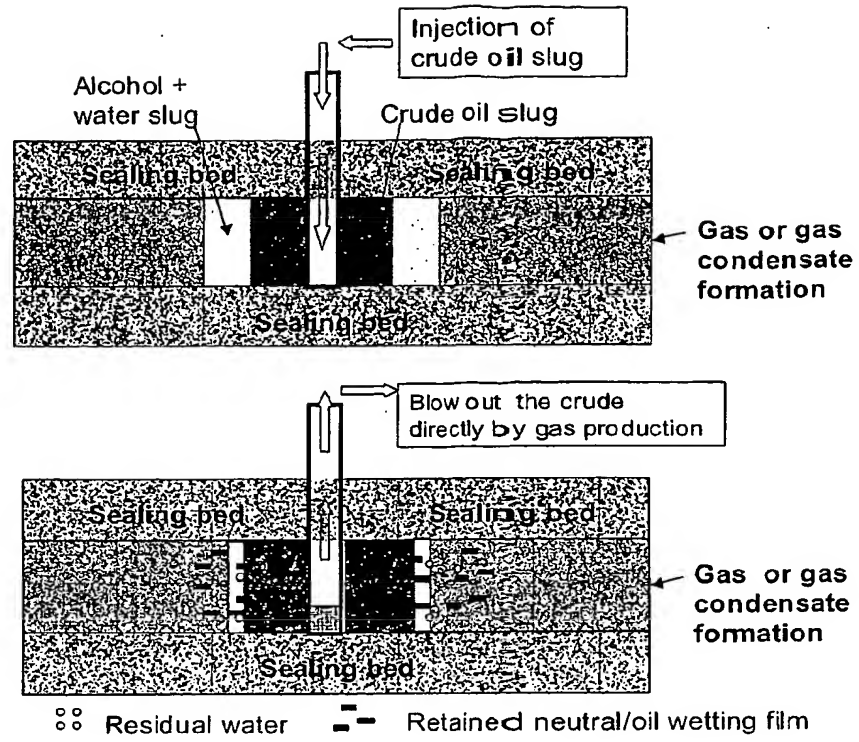


Fig.5c

Fig.5d

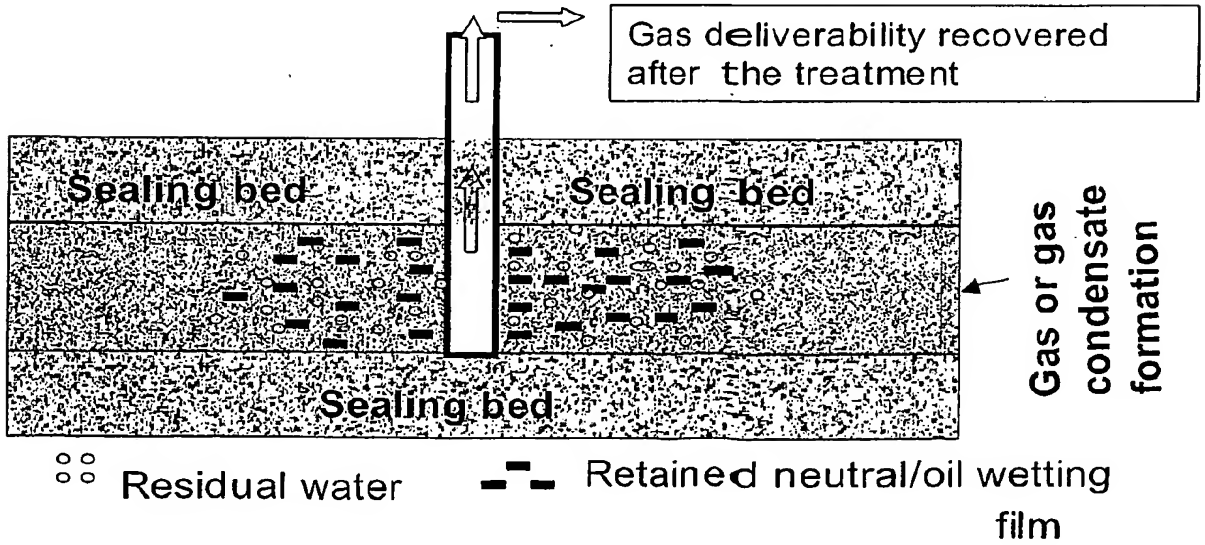


Fig. 5e

Fig. 6 Method 3 of treatment for gas or gas condensate reservoir case

Fig.6a

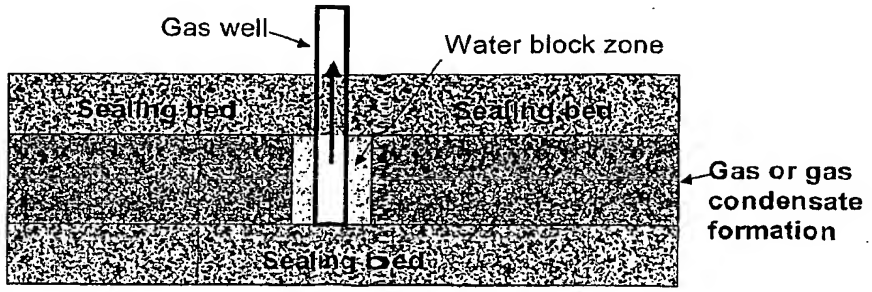


Fig.6b

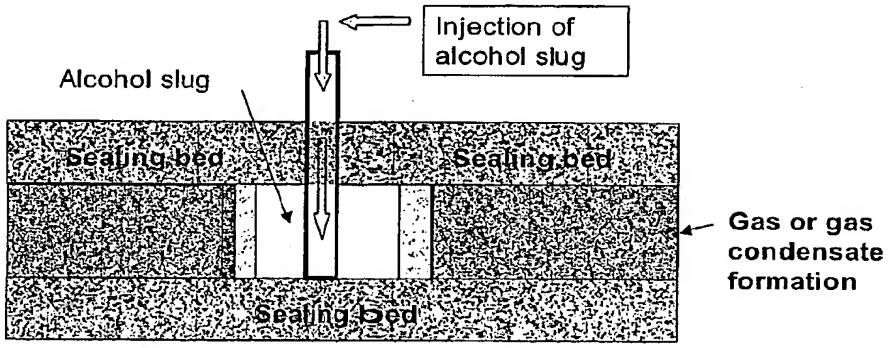


Fig. 6c

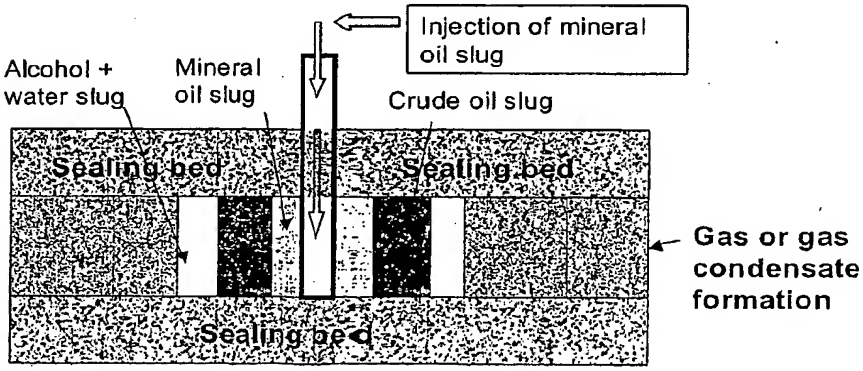
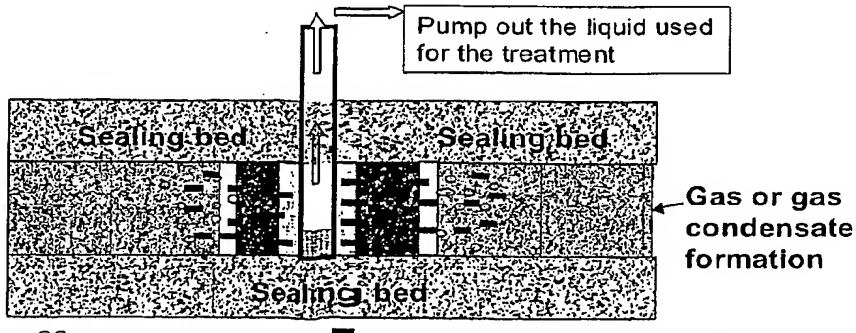


Fig. 6d



Residual water Retained neutral/oil wetting film

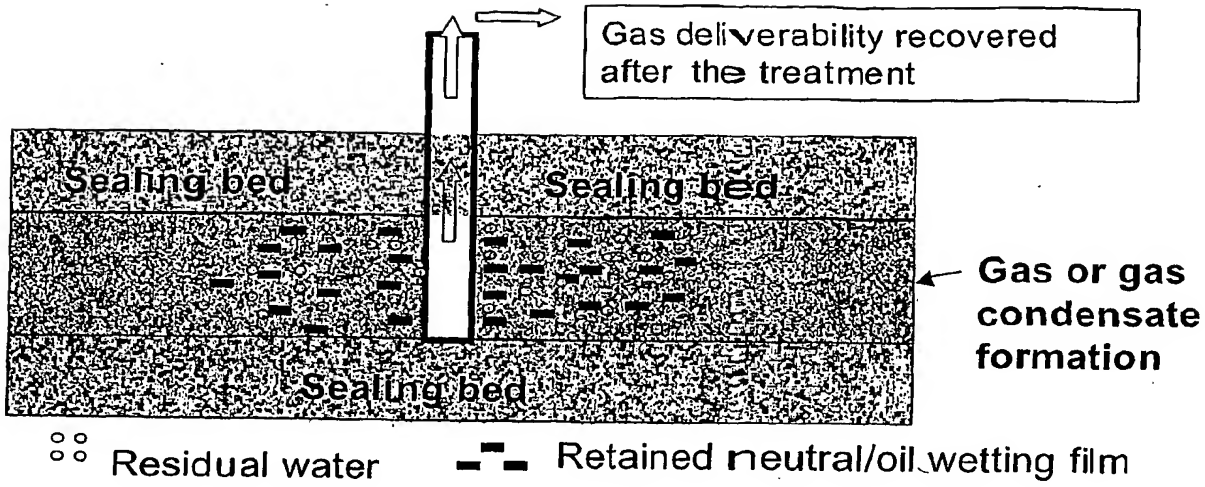


Fig. 6e

Fig. 7 Water coning case

Fig. 7a

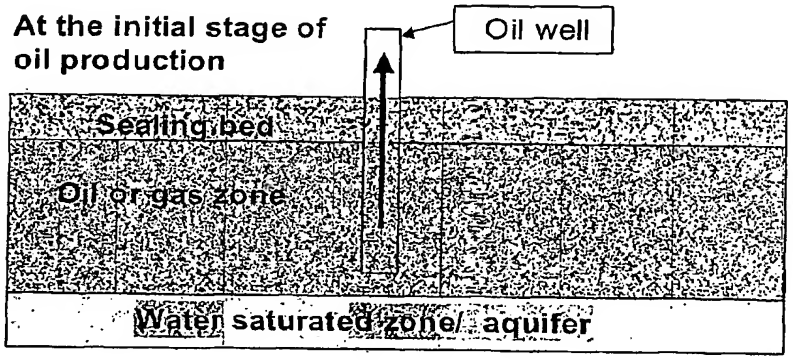


Fig. 7b

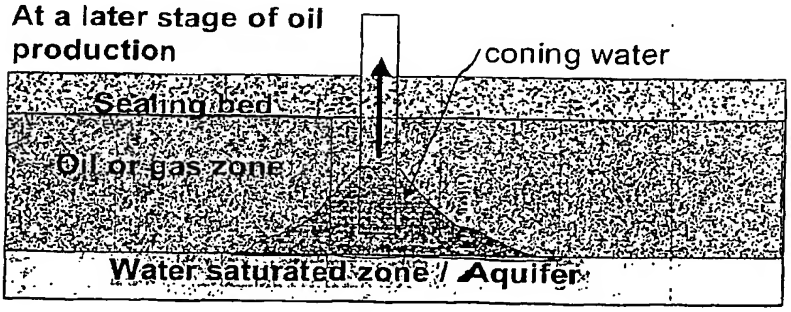
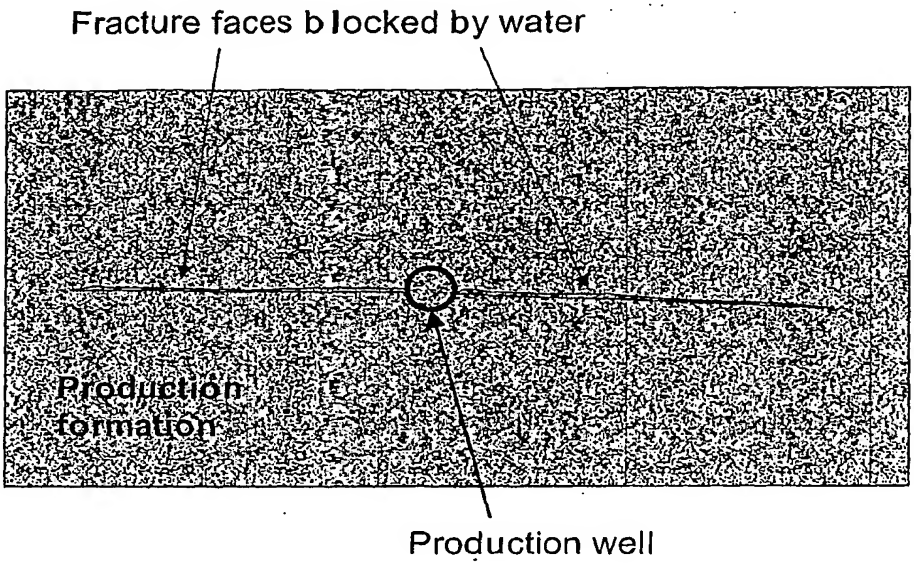
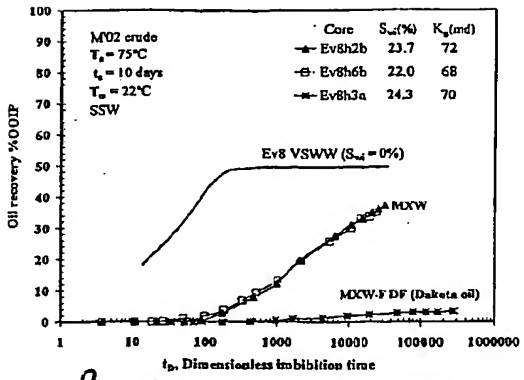
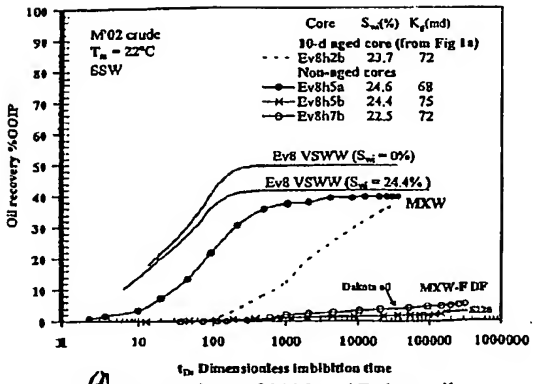


Fig. 8 Case with hydraulic fracture wells—plane view sketch

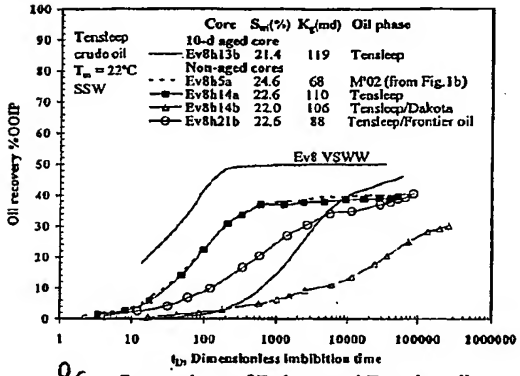




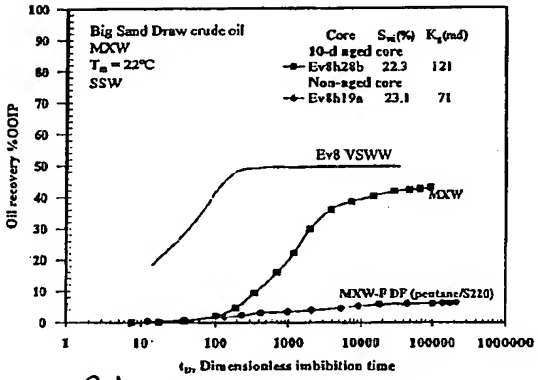
9a. Dakota oil displacing M'02 crude after 10-day aging



9b Comparison of S220 and Dakota oil displacing M'02 crude without aging



9c Comparison of Dakota and Frontier oil displacing Tensleep crude without aging



9d Pentane/S220 displacing Big Sand Draw crude without aging

Fig. 9 Wettability alteration was induced by displacement of crude oil with mineral oil or paraffinic oil directly.

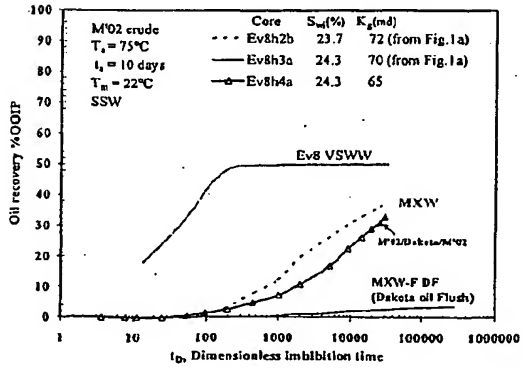
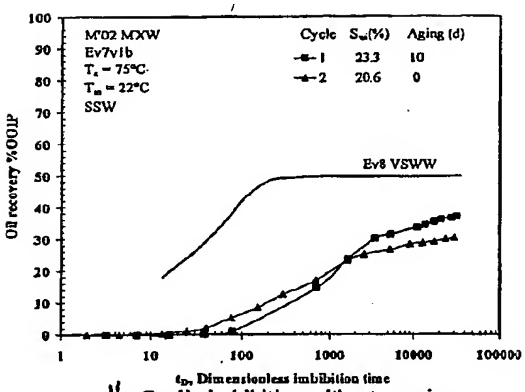
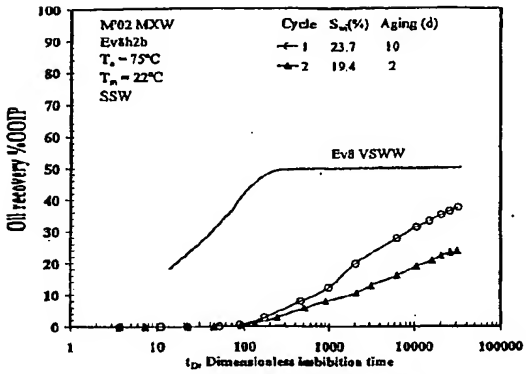


Fig. 10 Re-exposing surface-precipitated asphaltenes to fresh crude oil resulted in increased water wetness.

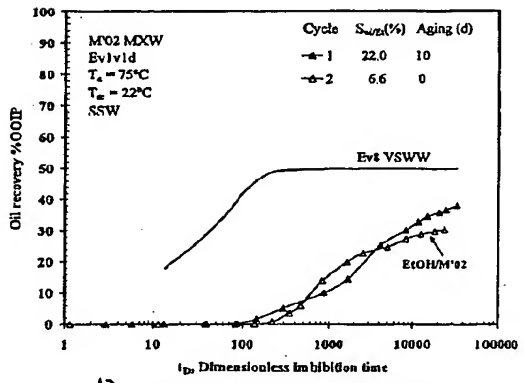


11a Cyclic imbibition without re-aging

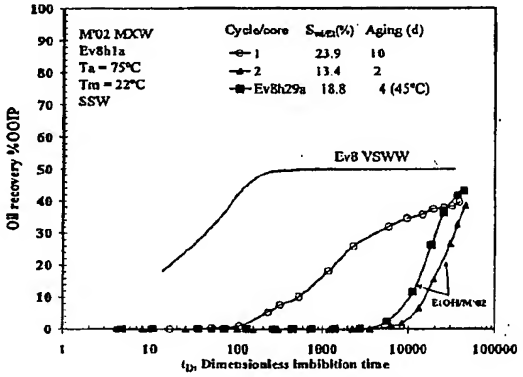


11b Cyclic imbibition with re-aging

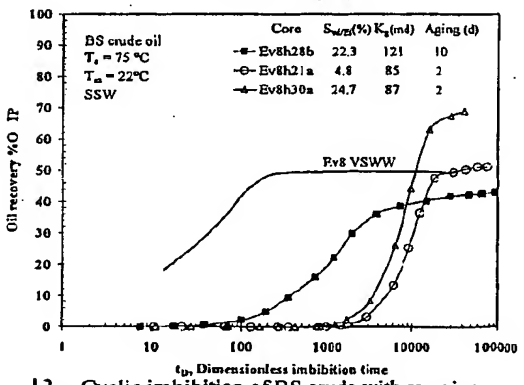
Figure 11. The effect of re-aging on wettability alteration



12a Cyclic imbibition of M'02 crude without re-aging

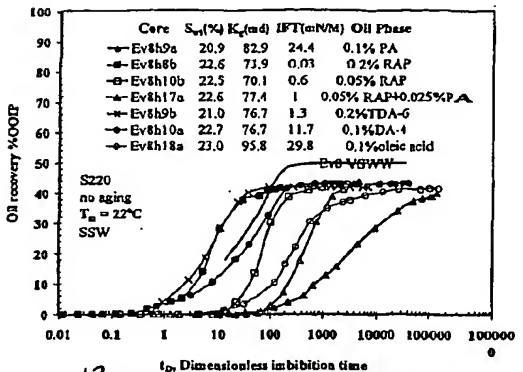


12b Cyclic imbibition of M'02 crude with re-aging

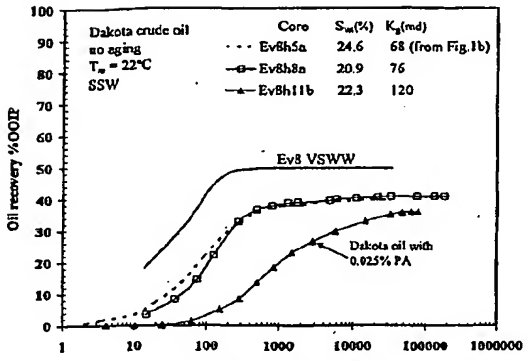


12c Cyclic imbibition of BS crude with re-aging

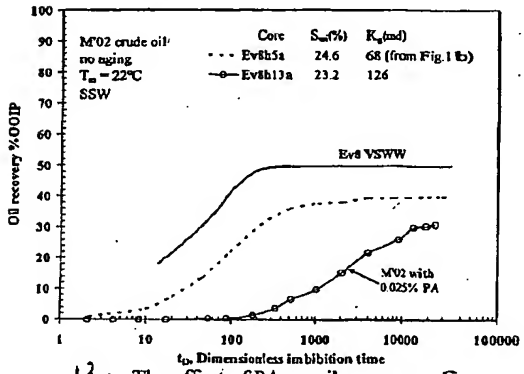
Fig 12 The effect of alcohol flush and re-aging on wettability alteration



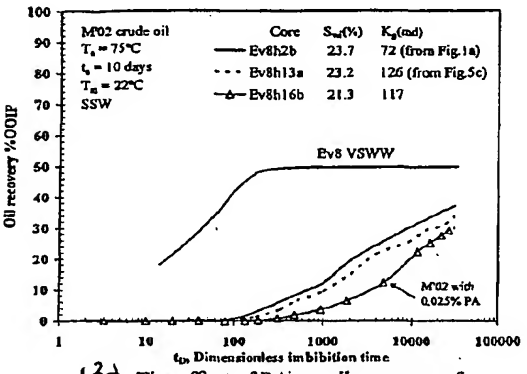
13a Screening oil-soluble surfactants



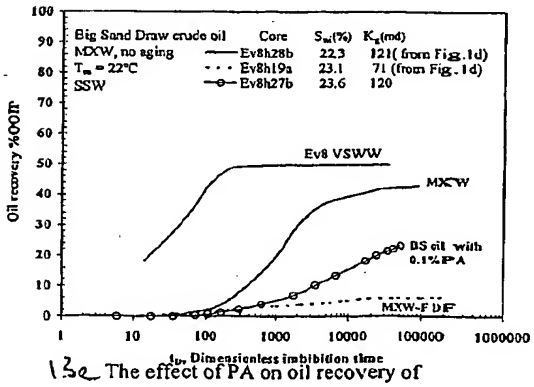
13b The effect of PA on oil recovery of Dakota oil



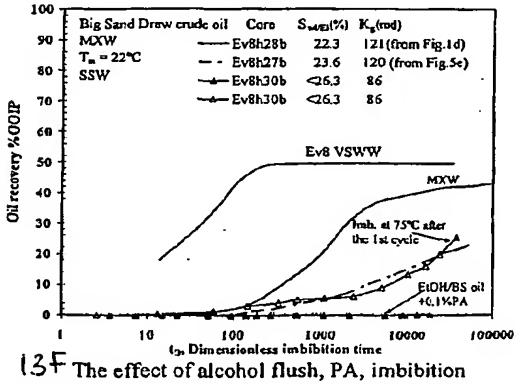
13c The effect of PA on oil recovery of M'02 without aging



13d The effect of PA on oil recovery of M'02 with aging



13e The effect of PA on oil recovery of BS oil without aging



13F The effect of alcohol flush, PA, imbibition temperature on oil recovery of BS oil without aging

Fig. 13 The effect of alcohol flush, oil-soluble surfactant and re-aging on wettability alteration for Berea sandstones

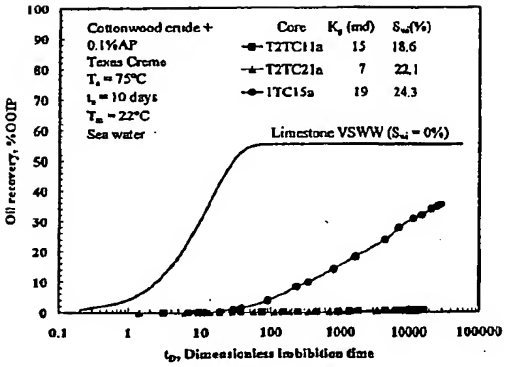
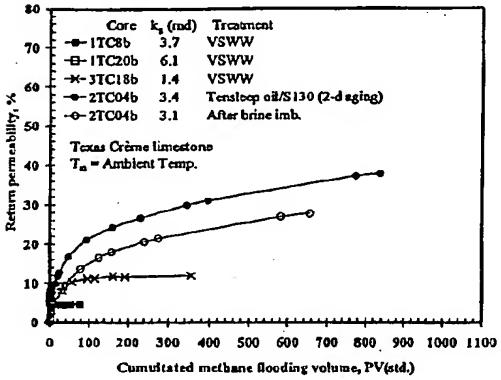
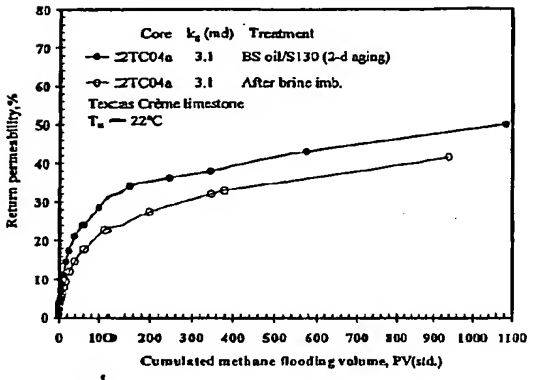


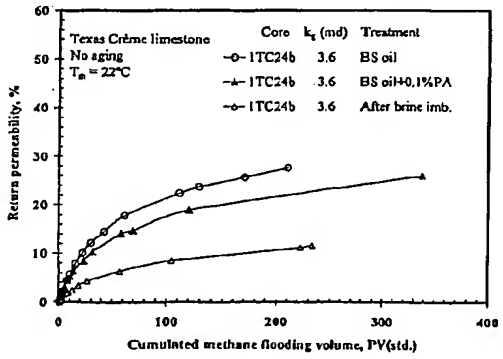
FIG. 14 The effect of Cottonwood crude oil and oil-soluble surfactant on wettability alteration for limestone



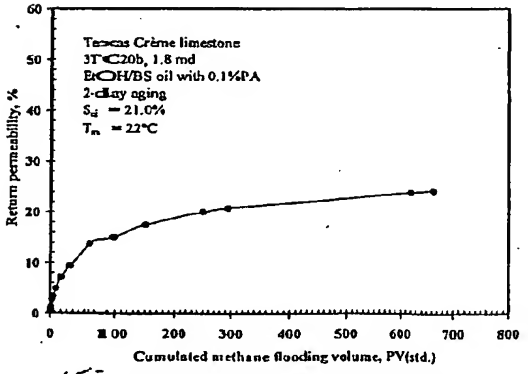
15a. Comparison between VSSW and Wettability induced by Tensleep/S130 with 2-d aging



15b Wettability induced by BS oil/S130 with 2-d aging



15c Wettability altered by BS oil or BS oil+0.1%PA without aging



15d Wettability altered by alcohol flush and BS oil+0.1%PA with 2-d aging

The effect of wettability alteration on gas return permeability

FIG. 15